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# UV Baked/Cured Photoresist Used as a Sacrificial Layer in MEMS Fabrications

by Thomas P. Takacs, Jeff Pulskamp, and Ronald Polcawich

ARL-MR-602 February 2005

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**Sensors and Electron Devices Directorate, ARL**

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MEMS fabrication requires the release of compliant mechanical structures. A sacrificial layer is typically used to provide as a structural layer on which device layers can be deposited and subsequently removed to leave a suspended or freestanding device. There are several sacrificial layers commonly used in MEMS fabrication such as $SiO_2$, polysilicon and polyimide. We have developed a sacrificial layer technique that can be used when many other sacrificial layers cannot be used. The use of photoresist that is Ultra Violet (UV) baked/cured as a sacrificial layer can save process steps, time and money. It can also be removed without the inherent problem of residues or stiction from wet processing, material by-products or the problematic issue of determining if the film has been completely removed.

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Microelectromechanical Systems (MEMS) fabrication techniques exploit the mature fabrication technology that is utilized in the production of Integrated Circuits (IC). There are three basic techniques used to fabricate MEMS: Bulk Micromachining, Surface Micromachining and Micromolding. Micromachining is the addition and subtraction of material, usually on a silicon substrate that defines three-dimensional (3D) structures.

Essential to all three MEMS fabrication techniques is the release of compliant mechanical structures. A sacrificial layer is typically used to provide a structure on which device layers can be deposited and subsequently removed to leave a suspended or freestanding device structure. There are several sacrificial layers commonly used in MEMS fabrication such as $SiO_2$, polysilicon and polyimide. These sacrificial layers are removed by either a wet or dry process that may introduce contaminates, residues or device damage due to high temperatures into a process. The determination of complete removal may be questionable when the sacrificial layer cannot be measured or visibly seen under the device structure

We have developed a sacrificial layer technique that can be used when many other sacrificial layers cannot be used due to the inaccessibility of equipment, temperature constraints or the unavailability of a specific film or process. The use of photoresist that is Ultra Violet (UV) baked/cured as a sacrificial layer can save process steps, time and money. It can also be removed without the inherent problem of residues from wet processing, material by-products or the problematic issue of determining if the film has been completely removed.

In this paper we show how UV baked/cured photoresist can be used as a sacrificial layer for the fabrication of MEMS devices. The removal of this sacrificial layer introduces no contaminates, residues or device damage than a standard $O^2$ plasma (ash). We discuss a simple metal bridge structure to demonstrate the potential uses of this technique.

Clariant AZ5214e Photoresist was deposited on to the surface of a silicon wafer. The photoresist was patterned in accordance with (IAW) the manufacturers recommendation for exposure and development times. The photoresist was then UV baked/cured to 230 °C. The bake and curing combines heat with ultraviolet light to cross link polymers in the photoresist, creating a resist pattern that is both physically and chemically hardened.

Photoresists are typically three component systems made up of a phenolic novolak resin, a photoactive diazoquinone ester and a solvent. The photoactive compound (PAC) serves as a dissolution inhibitor for the novolak resin. Upon exposure to UV energy, the PAC reacts with moisture in the resin to form carboxylic acid and is transformed into a dissolution enhancer. In addition to the cross linking reaction, thermal condensation reactions will occur in the novolak resin upon exposure to elevated temperatures. The two basic condensation reactions occur at approximately 140-150 °C and 200+ °C. The reaction mechanics are shown in figure 1 (*1*).

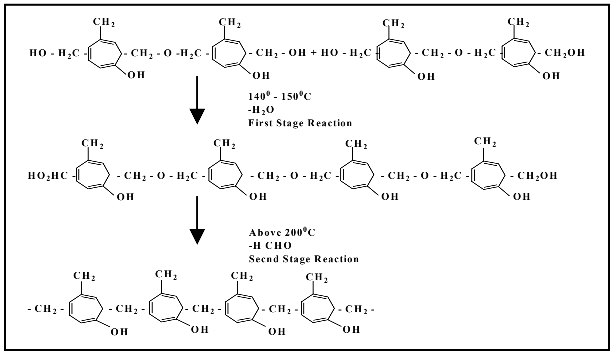


Figure 1. Novolak resin reaction mechanics.

The UV baked/cured process is conducted in a systematic set of steps to increase temperature and UV intensity, to keep the resist from flowing and changing shape. The temperature achieved with the UV baked/cured process far exceeds the glass transition temperature of the photoresist. To prevent the resist from flowing at these high temperatures, the resist must be UV cured prior to temperature ramping (*2,3,4*).

The UV source has a wavelength of 280 nm – 330 nm and the intensities are controlled in three ranges High (267 mW/cm$^2$), Medium (105 mW/cm$^2$) and Low (2 mW/cm$^2$). The process for the UV baked/cured is performed by holding the temperature at 90 °C for ten seconds and the UV intensity at low and medium for five seconds each to skin the surface of the photoresist for retaining the shape. Then the temperature is ramped from 90 °C to 230 °C in 140 seconds with the UV intensity at High, as shown if figure 2.

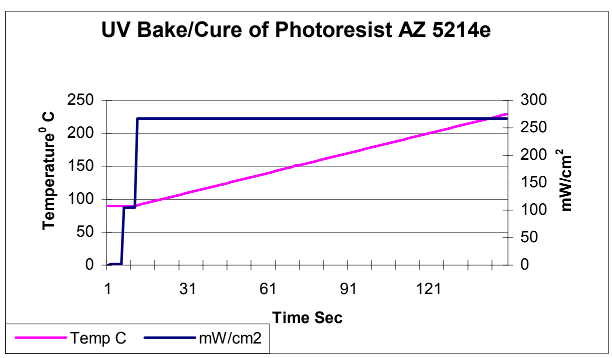
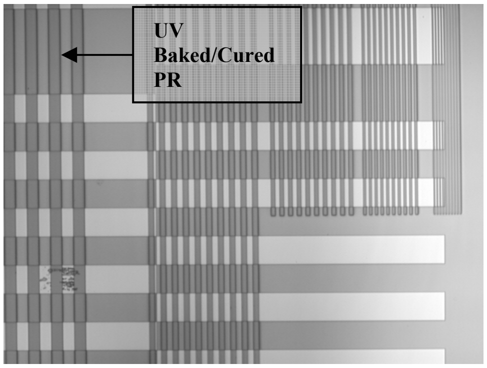



Figure 2. UV cure recipe profile.

The cross-linked photoresist is now stable enough for a second layer of photoresist to be spun over it. An adhesion promoter is not required in this step. The photoresist was exposed and developed IAW the manufacturers recommendation. This process results in a two layer patterned structure (figure 3) in which the second or top layer is used as a lift off layer for a subsequent metal deposition.



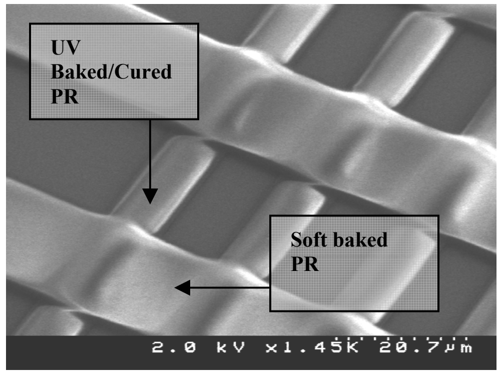
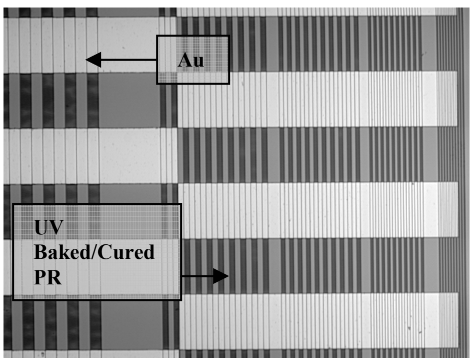



Figure 3.  Patterned softbaked photoresist over UV cured photoresist.

A 200 Å Ti and 1.25 µm Au film is evaporated onto the surface of the wafer and the wafer is then placed into an 85 °C bath of Baker PRS-3000 Stripper to remove the second layer of photoresist and the unwanted metal, which is a standard lift-off process.  The resist stripper does not attack the bottom UV bake/cured photoresist layer.  Figure 4 shows UV baked/cured photoresist intact after metal lift-off.



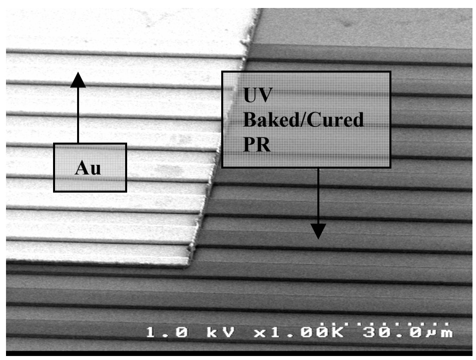
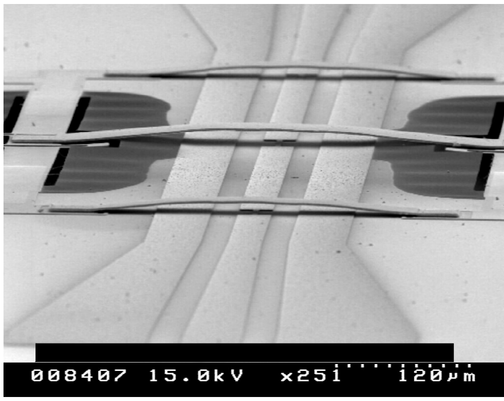


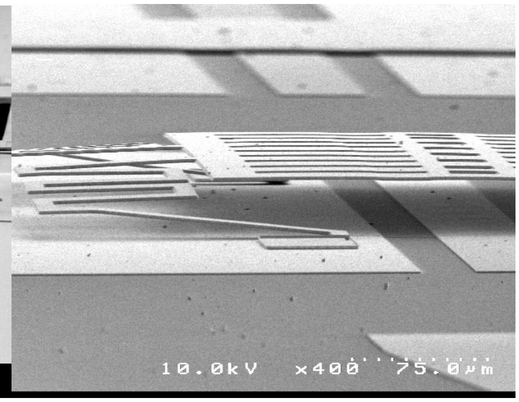

Figure 4.  UV Cured photoresist is intact after Au deposition and liftoff of soft baked photoresist.

The UV baked/cured photoresist is then removed by an $O_2$ plasma (ashed).  The final result is a metal bridge that was formed over the UV baked/cured photoresist.

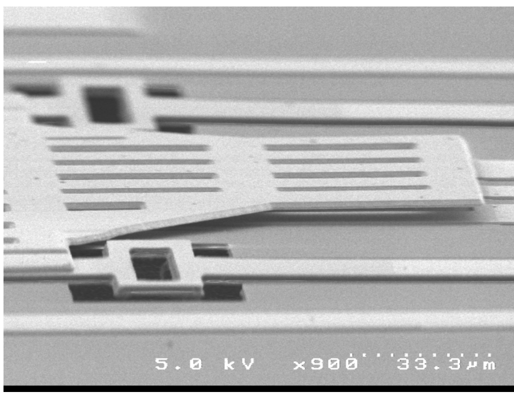
Using this modest technique we have been able to create complex structures.  Some examples are shown in the following images.



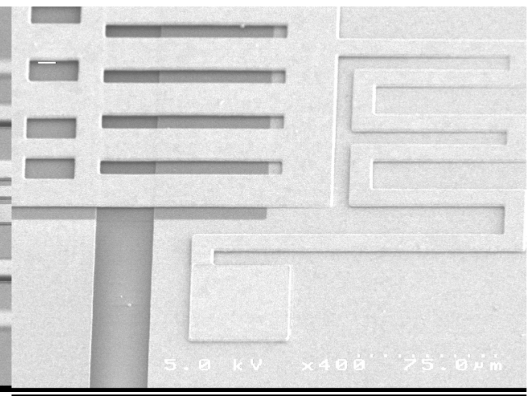

(RF Piezoelectric Switch with Au Contacts)




(RF Electrostatic MEMS Switch)




(Piezoelectric Capacitive RF MEMS Switch Au Plate)




(Piezoelectric Capacitive RF MEMS Switch Au Plate)

## Summary

The use of sacrificial layers in the fabrication of MEMS devices continues to be a fundamental process in the development of 3D structures. The availability of various processes and procedures for the fabrication of these devices is necessary to increase the complexity of devices. The use of an UV baked/cured photoresist as a sacrificial layer was developed for the purpose of MEMS fabrication. The use of the UV baked/cured photoresist method is an alternative to other sacrificial layers and can be adapted for numerous uses.

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